01-222N(E) -- ADVANCED PURIFICATION AND ENERGY SPREAD COMPENSATION FRAGMENT SEPARATOR CONCEPTS

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Purpose: Since the early 1990s in the field of low energy nuclear science there has been worldwide interest in an advanced facility capable of producing energetic, high-quality beams of radionuclides. The purpose of this LDRD project is to develop design concepts for the major components of the Rare Isotope Accelerator (RIA). This project aims to develop a large acceptance fragment separator to select reaction products and minimize their energy spread before injection into a large gas cell. This is a key component of the new paradigm combining fragmentation and ISOL technique to obtain low-energy radioactive beams of high quality from all chemical elements.

Approach: The novel concept of stopping fragmentation products in a large gas cell before reacceleration requires a very high performance from the fragment separator feeding the ions into the gas cell. It also requires a much better knowledge of the energy loss process at energies in the 100-400 MeV/u range then was previously available. We have studied both the basic energy loss process in this energy range and the ion optics constraints, selectivity and final fragment beam monochromaticity then can be obtained with conventional design and more advanced design for the fragment separator.

Technical Progress and Results: The task of the fragment separator feeding the gas cell is to collect the largest fraction possible of the reaction products, provide selectivity against contaminants and finally minimize the momentum spread of the wanted isotopes before injection into the gas cell. Some of these tasks pull the design of the device in opposite directions and make its realization difficult. The parameters that have been discussed for the fragment separator are a momentum acceptance of ± 9%, and angular acceptance of ± 50mrad and enough resolution to achromatize the outgoing recoil beam down to E/E = 0.2%. These requirements far exceed the capabilities of any existing fragment separator, which typically has an acceptance of ± 1% to ± 3% in momentum and no capabilities of reducing the momentum spread of the outgoing reaction products. The minimal fragment separator design that can approach the set requirements involves essentially one and a half fragment separator and is shown schematically in Fig. 1.

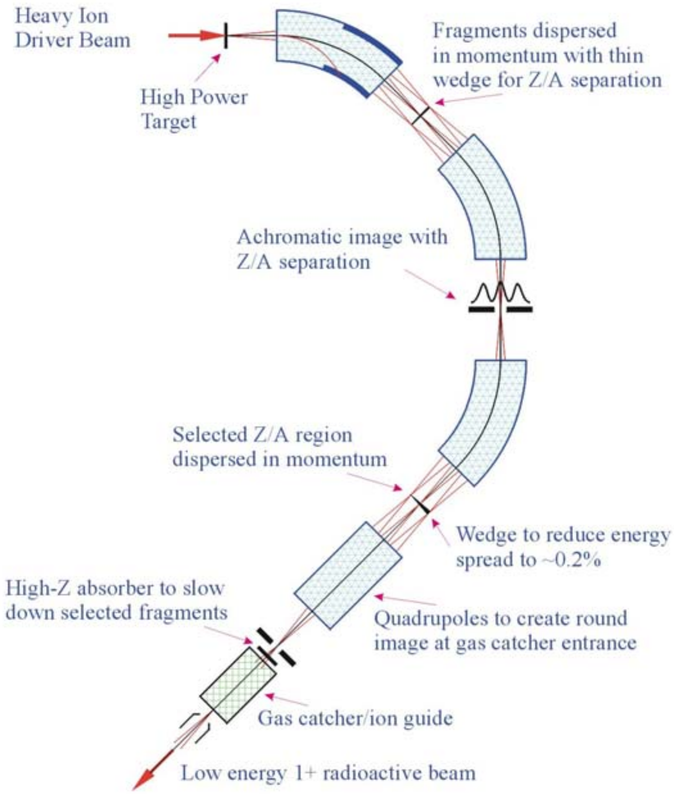

Figure 1. Schematic layout of a fragment separator followed by an additional momentum dispersive stage to achromatize the recoil beam before injection into the gas cell system.

The first two sections of the fragment separator transport the reaction products of interest while filtering out the primary beam and other products, which would affect the operation of the gas cell. It uses 2 momentum dispersive sections separated by a degrader to perform this task, the second section being tuned to a momentum corresponding to the initial momentum of the recoils of interest minus the momentum loss by that particular specie in the degrader. The last section of the fragment separator is used to disperse the selected recoils according to momentum and match this dispersion to a second wedged degrader so that all particles will lose just the right amount of energy going through that degrader to come out with a fixed uniform energy.

This approach, however, upon closer scrutiny, has associated with it a number of difficulties. The first difficulty comes from the fact that while the selection obtained in the first two sections by the degrader removing an amount of energy which depends on the isotope, this no longer provides much of a selection once the momentum acceptance of both sections becomes too large. This is shown in Fig. 2 where the yield at the back of the separator obtained with the program LISE with and without degrader is compared.

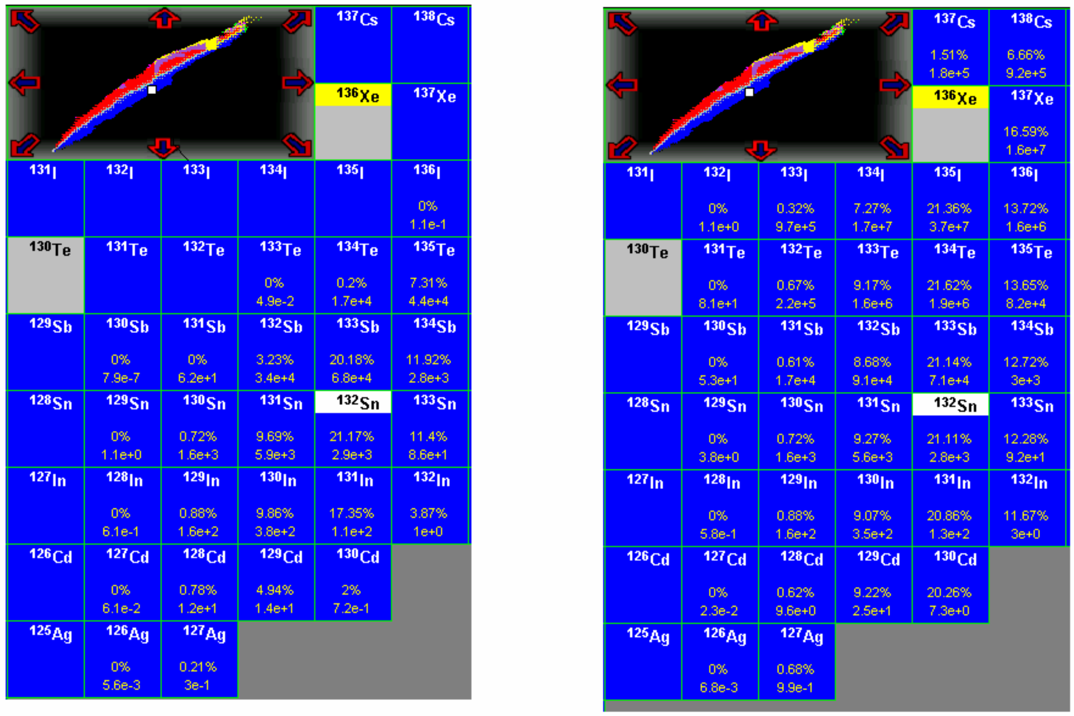

Figure 2. At the right is the yield of ^{132}Sn and neighboring isotopes from ^{136}Xe fragmentation without the presence of an intermediate degrader. At the left is the yield from the same reaction with an optimum degrader to select ^{132}Sn.

The selectivity is very poor because of the large momentum acceptance of both sections and the presence of such contamination will eventually limit the amount of primary beam that can be accepted without saturating the gas cell at the end of the fragment separator. Thicker degraders can be used but this is eventually limited by charge state fractionation and straggling in the degrader. These two effects are actually predicted from extrapolation of measurements at lower and higher energy since there was a severe lack of experimental information in the energy range of interest. To remediate this situation, we undertook a series of measurements on stopping power and straggling of various beams from Ar to U at energies between 100 and 400 MeV/u. These measurements were carried out at the FRS fragment separator at GSI where beams of the proper energy are available. These measurements were very successful, and the results are being analyzed and will be used to improve the quality of the simulations being used to determine the effect of the degraders.

The final part of the fragment separator in Fig. 1 achromatizes the recoil beam to minimize the range straggling in the gas cell and hence the size the gas cell must have to stop a large fraction of the recoils. The final range straggling of the residues comes from two contributions: 1) the intrinsic range straggling which would be present even for a perfectly monoenergetic beam due to the statistical nature of the stopping process, and 2) the range straggling coming from the residual energy spread and hence range spread of the beam. Both components become more important as the energy at which the beam is achromatized increases. We have tested the achromatization of the beam at high energy again at the FRS fragment separator with SiO_2 glass type wedged degrader with optical quality surfaces and found that with the high resolving power of the FRS a range straggling close to the intrinsic range straggling limit could be reached. While this is in itself a very promising result, it appears clear that being able to further reduce the energy at which the achromatization takes place would be beneficial. This however can no longer be done with the technique used so far because of the charge fractionation as the energy is lowered which spreads a given momentum bite into many momentum-over-charge bites. This destroys the achromatization process since the momentum/position correlation is lost. A possible solution is the introduction of another selection device such as a velocity filter, which is independent of the charge of the recoils of interest. We have built a small version of such a velocity filter and tested it on-line at ATLAS to determine its characteristics and are now performing ion optical calculations to determine the optimum way to introduce such a device in the fragment separator design. We expect that such an addition will both decrease the range straggling and increase the selectivity of the fragment separator.

Specific Accomplishments: Preliminary results on the experiments performed have been presented at conferences, and papers in refereed journals will follow once the analysis is completed:

G. Savard, "The RIA Project," ISOL '01 International Conference, Oak Ridge, TN (March 11-14,2001).

G. Savard, "The U.S. Rare Isotope Accelerator Project," 2001 Particle Accelerator Conference (PAC2001), Chicago, IL (June 18-22, 2001).